Combiner Implementation Revision to Incorporate Custom Fusing Automation

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13. ABSTRACT (*Maximum 200 words*)

NCSU developed a strategy with a Defense Apparel Manufacturer (American Apparel) and an equipment manufacturer to design, construct, and implement economically justifiable, commerical equipment to automate the BDU pocket flap fusing operation and demonstrate the benefits of automation to the military apparel contractors. The "custom commercialization" strategy employed through this project has resulted in technology that is available for sale to other military contractors. This project has demonstrated clearly that automation does play a major role in the overall strategy of the DSCP to reduce the costs of goods while improving quality, delivery, and surge capacity. As the skilled apparel workforce in the US continues to decline, companies like Mid-South Sewing Machine Sales will be able to provide affordable, "customized" automation to meet the ever demanding needs of the military.

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DLA-ARN Short-Term Project Report

Hardware Automation and Control (HAC1) To Incorporate Custom Fusing Automation (Based on DLA Building Blocks)

Contract Number	SPO100-95-D-1015
Contractor	North Carolina State University
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Delivery Order Title	Combiner Implementation Revision to Incorporate Custom Fusing Automation
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North Carolina State University Research Project #: 533904
Timothy G. Clapp
Principal Investigator

Executive Summary

The purpose of this contract (SPO100-95-D-1015-001) was to develop a strategy with a Defense Apparel Manufacturer (American Apparel) and an equipment manufacturer to design, construct, and implement economically justifiable, commercial equipment to automate the BDU pocket flap fusing operation and demonstrate the benefits of automation to the military apparel contractors.

The project was initiated August 27, 1996, and completed October 31, 1998, at a cost of $419,533. The metrics shown in Table E.1 demonstrate the success of the project.

Table E.1. BDU Pocket Flap Fusing Automation POST Metrics

Metric*	Old Value	Resultant Value
DLA-ARN Investment AA Investment	$419K $120K	$523K 10 year NPV (AA) **$1.5M 10 year NPV (all BDUs)**
Direct Labor cost	$205K/yr	$97K/yr **($108K/yr Savings)**
Training Time	8 weeks	2 weeks **(75% Reduction)**
Quality	85% operator defects	10% operator defects **(88% Reduction)**
Surge capacity	1X/operator	2X/operator **(2X , 9 wks faster)**
Training Costs	Ave $8,640/operator	Ave $2,160/operator **($6480/operator savings)**

* Savings Based 1.25M/year BDU production at AA

The "custom commercialization" strategy employed through this project has resulted in transferring the technological developments in previous DLA-funded programs to commercial equipment manufacturers, including ARK, Inc. and Mid-South Sewing Machine Sales. This technology is available for sale to other military contractors.

A technology transfer program has been established to contact military contractors. Miltary contractors have been contacted by mail and through the DLA-ARN website. The equipment has been demonstrated at the apparel equipment show and received interest from civilian and military contractors. The equipment is running in a production environment and available for open demonstration at American Apparel in Fort Deposit, Alabama.

This project has demonstrated clearly that automation does play a major role in the overall strategy of the DSCP to reduce the costs of goods while improving quality, delivery, and surge capacity. As the skilled apparel workforce in the US continues to decline, companies like Mid-South Sewing Machine Sales will be able to provide affordable, "customized" automation to meet the ever demanding needs of the military.

1.0 Introduction

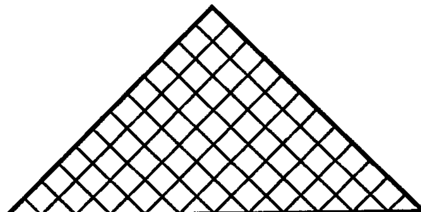
The textile and apparel base in the US continues to change. Most visible in these changes is the shrinking labor pool employed in the assembly of garments. During the first seven months of 1995, the US apparel industry lost 51,000 jobs according to a report in *Women's Wear Daily* and the textile industry, 27,000 jobs. These job losses are a result of plant closings, off-shore sourcing, and the use of automation in manufacturing. The textile complex is changing through mergers, acquisitions, right sizing, supplier-producer partnerships, the creation of global firms and integrated supply systems. The military supply chain is changing dramatically through programs such as Virtual Prime Vendor (VPV) and Balanced Inventory Flow Replenishment System (BIFRS) where inventory is reduced and the need to ensure high quality, on-time devlivery is essential.

The changes taking place affect the supply of military apparel in part due to the small production volumes required and the requirements of a customized military product in a short time. "Soft technologies" alone cannot create the changes necessary to accomplish the new requirements. The hardware currently being used to produce military apparel relies on a human operator almost exclusively. Approximately 25-40 percent of the cost of military apparel products is attributed to direct labor. Initiatives to reduce garment costs and maintain a strong US apparel manufacturing base require the implementation of hardware to deskill and automate apparel manufacturing, thereby ensuring a strong, economically competitive apparel manufacturing base in the US. The implementation of automated equipment will also facilitate high quality, 24-hour, seven-day production capability to satisfy unforeseeable surge capacity.

North Carolina State University established a partnership with ARK, Incorporated, and later Mid-South Sewing Machine Sales to develop "customized commercial" equipment to meet the needs of the military contractors. BDU pocket flap fusing was selected as the operation to demonstrate the automation strategy. American Apparel was the military contractor selected to work with the design team to assist in the design, installation, testing, and evaluation of the technology in a real manufacturing environment.

The design team conducted a Quality Function Analysis (QFD) to identify the customer and technical requirements for the project. Figure 1.1 shows the House of Quality (HOQ) matrix which identifies the relationship between the customer requirements and the technical requirements. Figures 1.2 and 1.3 show the relative importance of the customer and techincal requirements, respectively. These requirements were used to guide the design.

BDU FusingCombiner



Tradeoffs	
Synergy ●	1.0
Compromise ■	-1.0

Direction of Improvement		
Maximize	↑	1.0
Target	✖	0.0
Minimize	↓	-1.0

Standard 9-3-1		
Strong	●	9.0
Moderate	○	3.0
Weak	▽	1.0

		Importance of the WHATs (1)	Part Feed Rate (1)	Flap Alignment (2)	Stack Tolerance (3)	Fused Part Tolerance (4)	Standard Machine Parts (5)	Feed Efficiency (6)	Loading Time (7)	OSHA (8)	Press Interface (9)	Error Detection (10)	Auto Load (11)	Auto Unload (12)
Direction of Improvement	1		↑	✖	✖	✖	↑	↑	↓	✖	↑	↑	↑	↑
Pair Cut Stacks	1	7.0	●	○	▽	○		●	▽			●		
Good Fused Parts	2	10.0		●	○	●						●		
Good Finished Stacks	3	7.0		○	●									●
Different Pocket Sizes	4	1.0		●	○	●		○				○		
Machine Reliability	5	8.0	●				●							
Machine Flexibility	6	5.0					○			○	●			
Machine Maintainability	7	7.0					●			●				
Affordable	8	9.0	●	○	●	●	●	●	○	●	●	●	○	○
Safety	9	10.0							○	●		○	○	○
Production Efficiency	10	8.0	●	○		○	○	●	●			○	●	●
Productivity	11	8.0	●	○	▽	▽		●					●	●
Tending Operation	12	5.0						●	○			●	●	●
Simple to Operate	13	5.0	○	▽	○		▽				▽		○	○
Operator Feedback	14	5.0		●	▽			●				●		
Production Monitoring	15	6.0						●						
Error Checking	16	8.0	○	●		○		●	○			●	○	○
Minimum Adjustments	17	5.0		●	●	●								
Press Fire Prevention	18	10.0								●		●		
Importance of the HOWs	1		321.8	308.9	207.3	243.5	209.7	408.9	141.1	273.4	105.6	437.9	229.8	280.6
Percent Importance of the HOWs	2		10.2	9.7	6.5	7.7	6.6	12.9	4.5	8.6	3.3	13.8	7.3	8.9
Max = 13.8 Percent Importance of the HOWs Min = 3.3	3													
Competitive Benchmarking Results	4													
Our Current Product	5													
Competitor 1	6													
Competitor 2	7													
Targets for Our Future Product	8													
			1	2	3	4	5	6	7	8	9	10	11	12

	Competitive Analysis (1)	Our Current Product (2)	Competitor 1 (3)	Priority Ranking (4)	Our Future Product (5)	Improvement Factor (6)	Market Leverage Factor (7)	Overall Importance (8)	Percent Importance (9)	Max = 8.1 Percent Importance Min = 0.8	
Pair Cut Stacks				11.0				7.0	5.6		1
Good Fused Parts				3.0				10.0	8.1		2
Good Finished Stacks				10.0				7.0	5.6		3
Different Pocket Sizes				17.0				1.0	0.8		4
Machine Reliability				6.0				8.0	6.5		5
Machine Flexibility				14.0				5.0	4.0		6
Machine Maintainability				9.0				7.0	5.6		7
Affordable				4.0				9.0	7.3		8
Safety				1.0				10.0	8.1		9
Production Efficiency				7.0				8.0	6.5		10
Productivity				8.0				8.0	6.5		11
Tending Operation				15.0				5.0	4.0		12
Simple to Operate				12.0				5.0	4.0		13
Operator Feedback				13.0				5.0	4.0		14
Production Monitoring				11.0				6.0	4.8		15
Error Checking				5.0				8.0	6.5		16
Minimum Adjustments				16.0				5.0	4.0		17
Press Fire Prevention				2.0				10.0	8.1		18

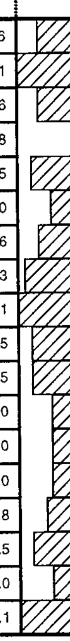


Figure 1.1. House of Quality for BDU Pocket Flap Fusing Machine

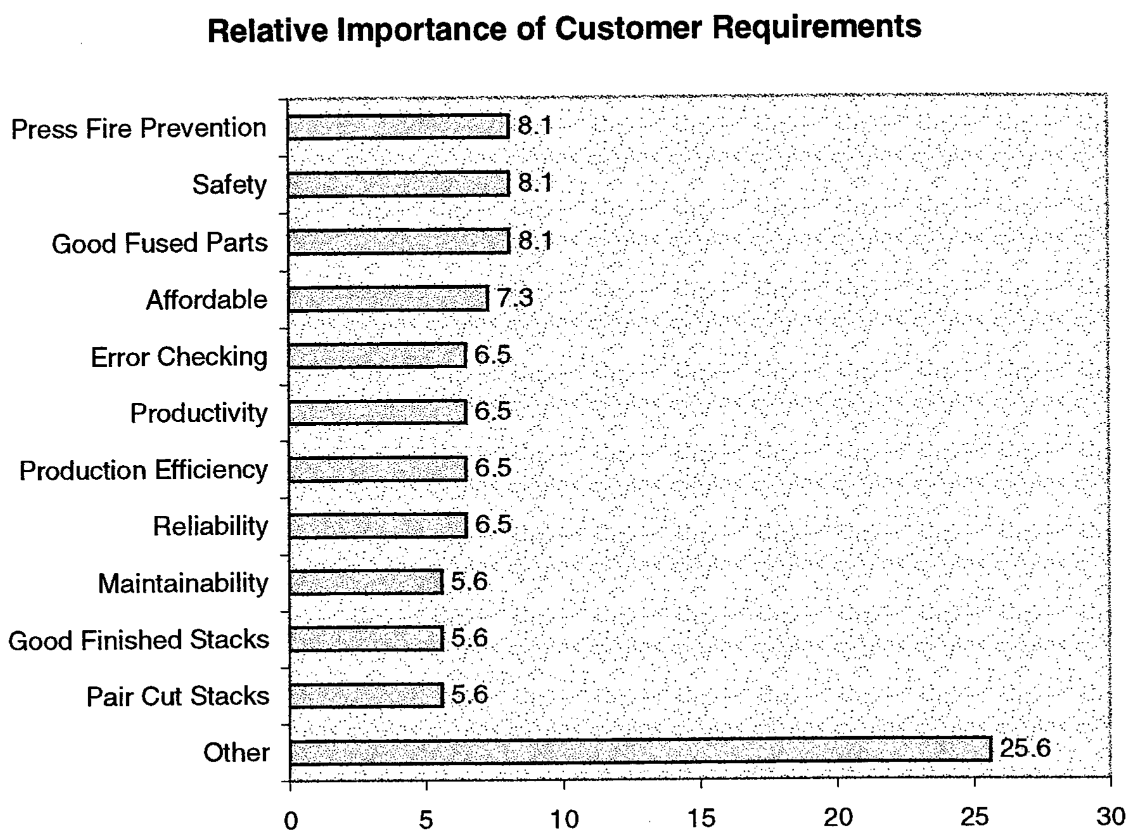


Figure 1.2. Customer Requirements Ranking

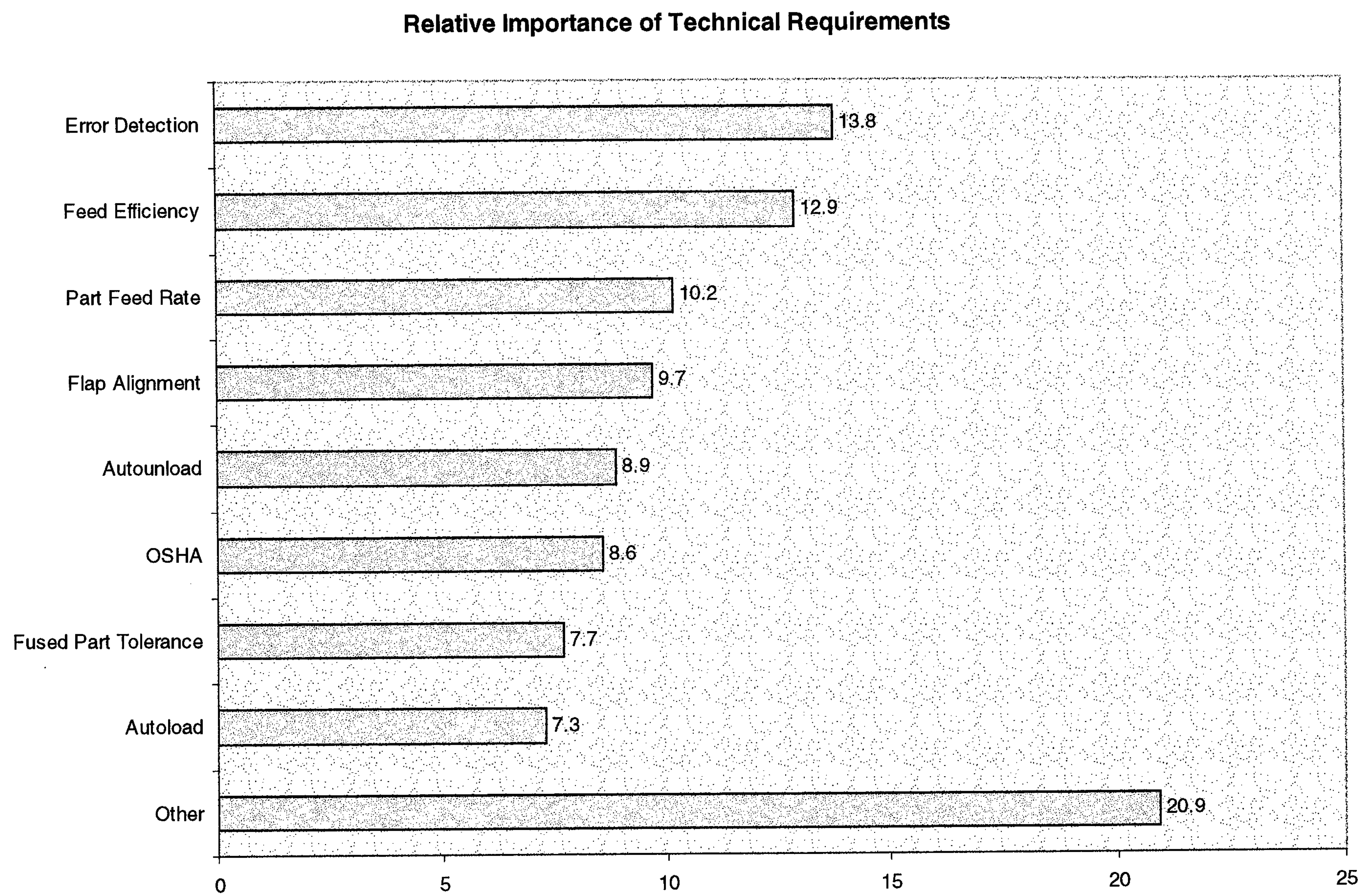


Figure 1.3. Technical Requirements Ranking

2.0 Equipment Description

The design team used the technical requirements to govern the design process. The team also utilized the "building blocks" of technology developed under DLA's MANTECH program. The building block technology included feeding, pick up, orientation, combining, and stacking as listed in Table 2.1. Flow Chart 2.1 of the BDU pocket flap fusing operation shows how the "building blocks" are utilized to design the automatic equipment. This technology greatly reduces the time and uncertainty when designing commercial apparel automation.

ARK, Incorporated conducted the detail design and construction. The equipment was installed at American Apparel in Fort Deposit, Alabama. American Apparel produces approximately 25,000 BDU uniforms per week.

The automatic fusing equipment is designed to be mounted to a standard fusing press. In the current manual operation, an operator takes a piece of fusing material and aligns the piece onto the BDU pocket material. Both pieces are fed into the fusing press as shown in Figure 2.1. Once fused, the pocket materail is stacked for subsequent processing. Occasoinally, the part does not exit the fusing press and accumulates in the heating zone of the press. When this occurs, a fire is likely and the entire manufacturing plant has to be closed.

The automatic equipment is designed to replace the manual operation and conduct a continuous error check to prevent fires from occuring. The equipment is broken into two major parts: the feeding system and the stacking system. The existing fusing press is between the two parts. Figure 2.2 shows a wide angle view of the production prototype feeding system built by ARK connected to the fusing press. Figure 2.3 shows the production prototype stacker attached to the exit side of the press.

The production prototype equipment was installed and evaluated. The equipment functioned at a production efficiency beyond expectations. However, a number of design improvements were identified in enhance the acceptance of a commercial model. These improvements included: 1) use of commercially-available components, 2) easy access for maintenance, 3) overall cost reduction, 4) user-friendly operator panel, 5) increases part size flexibility, and 5) simple electronic control.

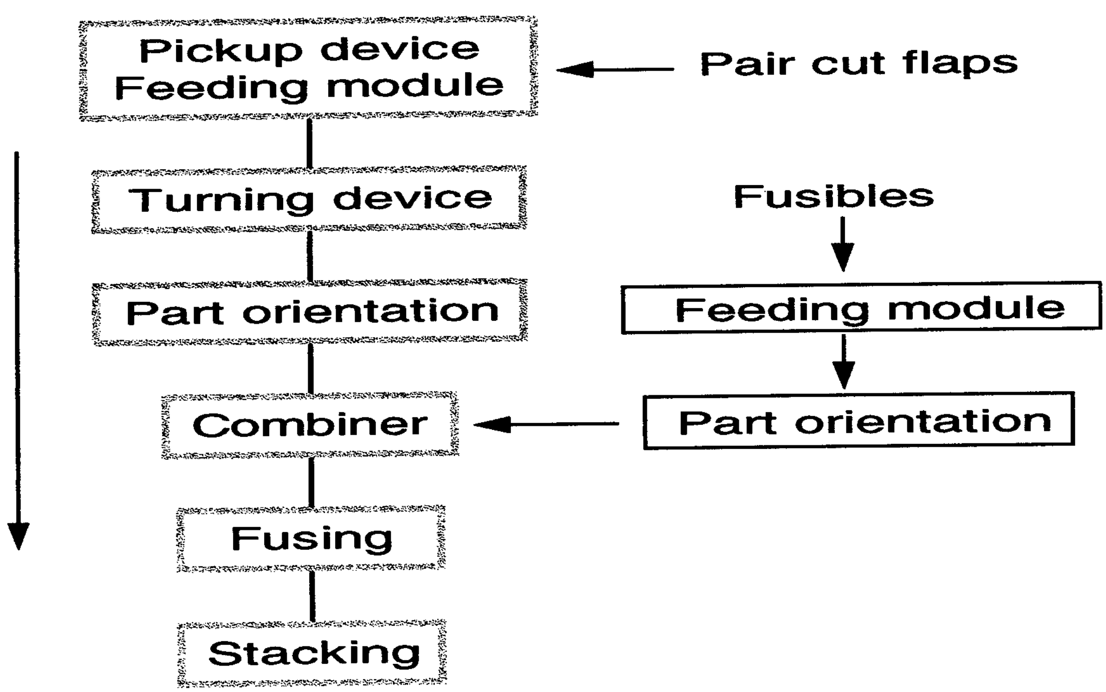
Mid-South Sewing Machine Sales (MSS) was selected to make design improvements and build the production unit. MSS is a complete machinery design builder with sales and service capabilities. The commercial equipment is designed using CAD software to make future costomization to other operations quick and easy.

MSS conducted a complete design review of the production prototype equipment running at American Apparel. Design changes were discussed with engineers at American Apparel and NCSU. Once the design changes were agreed upon, MSS began the design of the commercial equipment.

Table 2.1. "Building Blocks" of Technology Developed for Apparel Automation

BUILDING BLOCK	STATUS	RESEARCH PARTNERS
Pickup devices	Commercialized	NCSU/JetSew/CAR
Parts feeders	Commercialized	NCSU/ARK/JetSew
Part Turning	Commercialized	NCSU/ARK/JetSew
Part orientation	Production prototype	NCSU/ARK
Multiple part combining	Production prototype	NCSU/ARK
"Auto Hand" transport at needle	Production prototype	NCSU/ARK
Parts stacking	Commercialized	NCSU/ARK/JetSew
Fabric spreading	Production prototype	NCSU/ARK
Microprocessor controls	Commercialized	NCSU/ARK/JetSew/USL
Divide, turn, shade mark module	Commercialized	NCSU/ARK/JetSew
Front pocket bagger module	Production prototype	NCSU/ARK
Small parts serger module	Production prototype	NCSU/ARK

Flow Chart 2.1. BDU Pocket Flap Fusing Operation Sequence Diagram



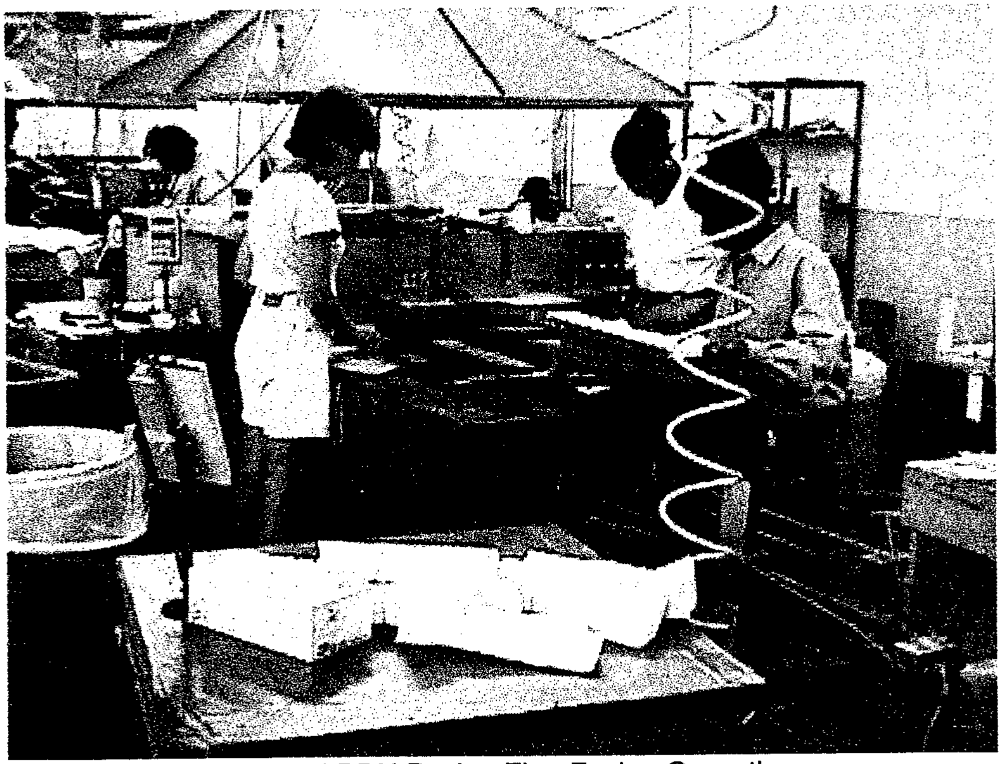


Figure 2.1. Manual BDU Pocket Flap Fusing Operation

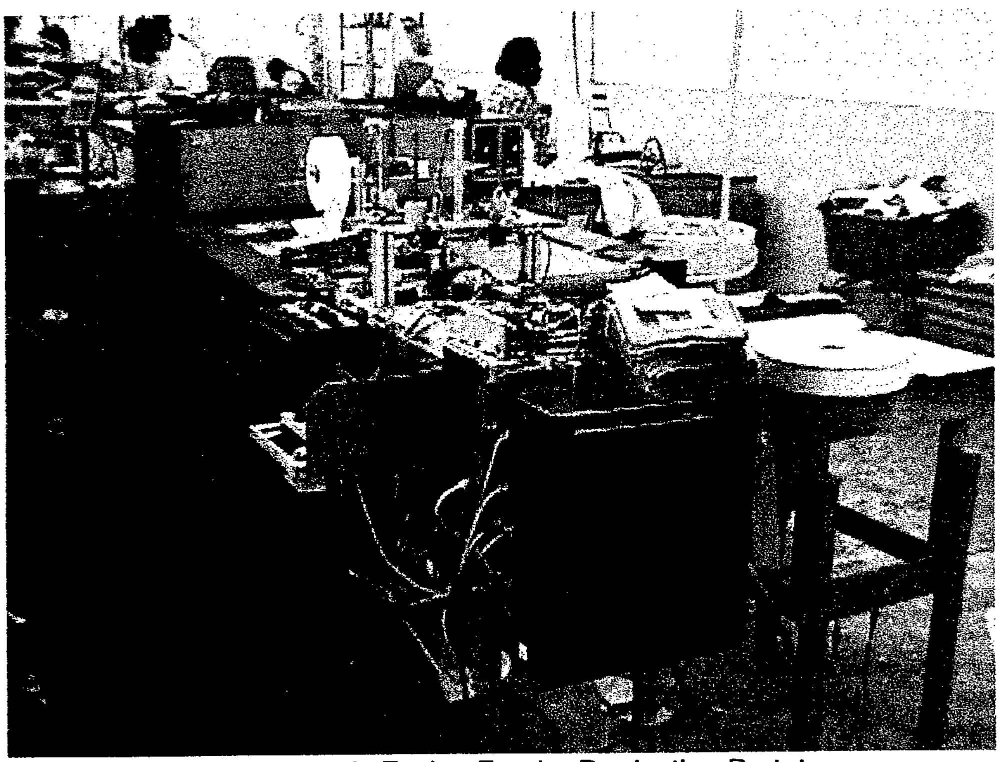


Figure 2.2. Automatic Fusing Feeder Production Prototype

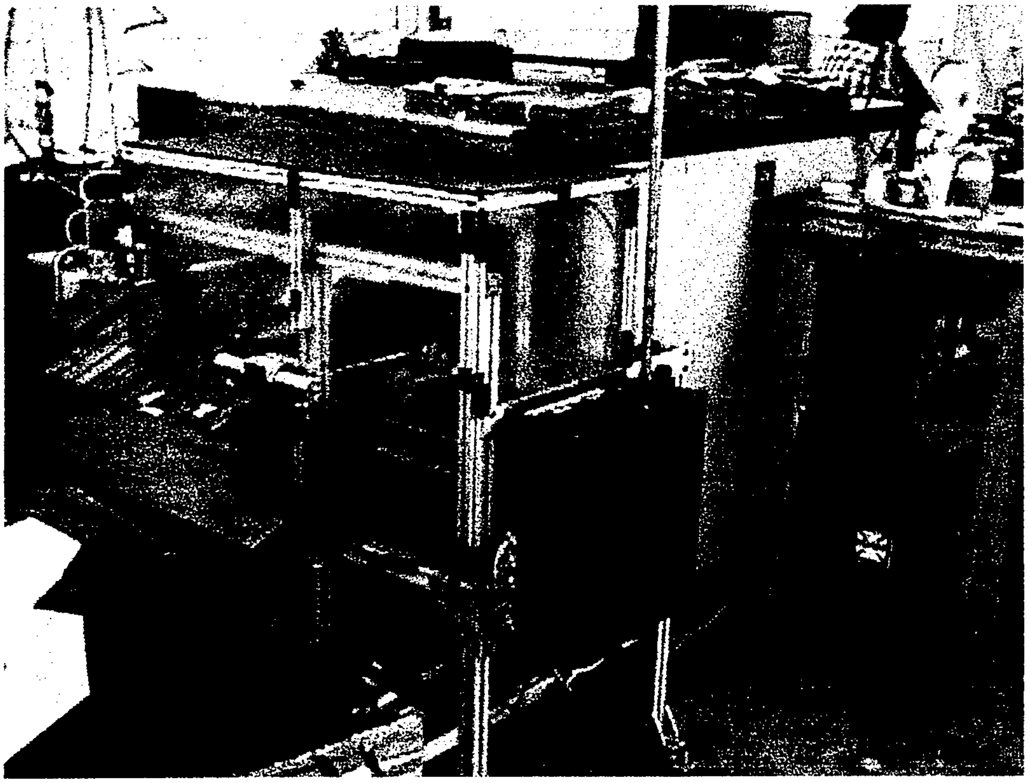


Figure 2.3. Automatic Fusing Stacker Production Prototype

Mid-South completed the design and exhibited the commercial equipment at the 1998 Bobbin Show in Atlanta, Georgia. The equipment was installed at American Apparel for testing and evaluation. Figures 2.4 and 2.5 show the commercial automatic feeding equipment and the stacking equipment, respectively. The equipment has a clean, professional look.

Improvements in the commercial design can be seen in the following figures listed in Table 2.1.

Table 2.1. Design Features of the Commercial Automated Equipment

Figure	Design Feature
Figure 2.6	Adjustable feeder to handle various pocket sizes
Figure 2.7	Uniform alignment of all part sizes
Figure 2.8	Programmable fusing length adjustment
Figure 2.9	Easy accessibility for maintenance
Figure 2.10	Simple PLC electronic control
Figure 2.11	Operator-friendly control panel
Figure 2.12	Accurate placement of BDU pocket flap on fusing press

This equipment is commercially-available for sale to military and civilian contractors by Mid- South Sewing Machine Sales.

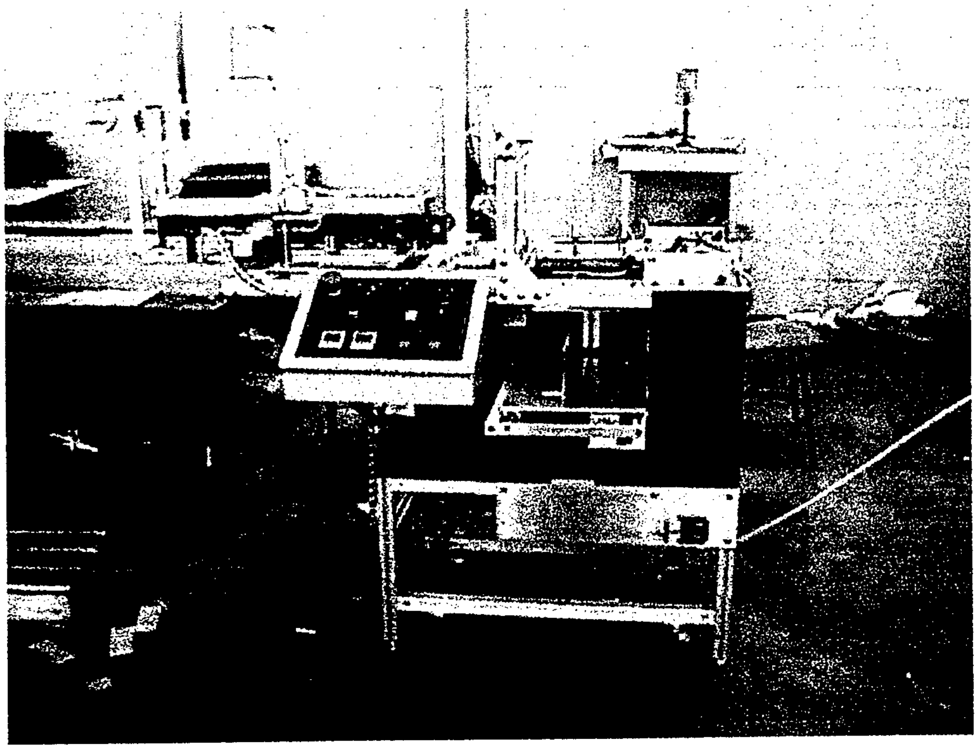


Figure 2.4. Commercial Fusing Feeder

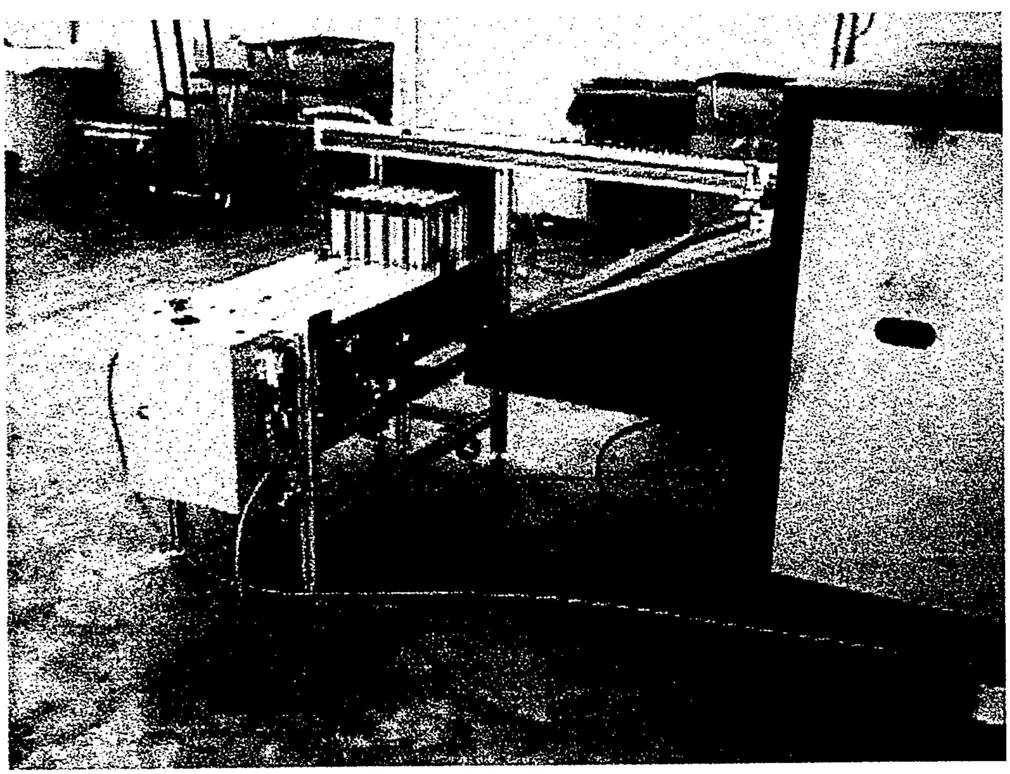


Figure 2.5. Commercial Fusing Stacker

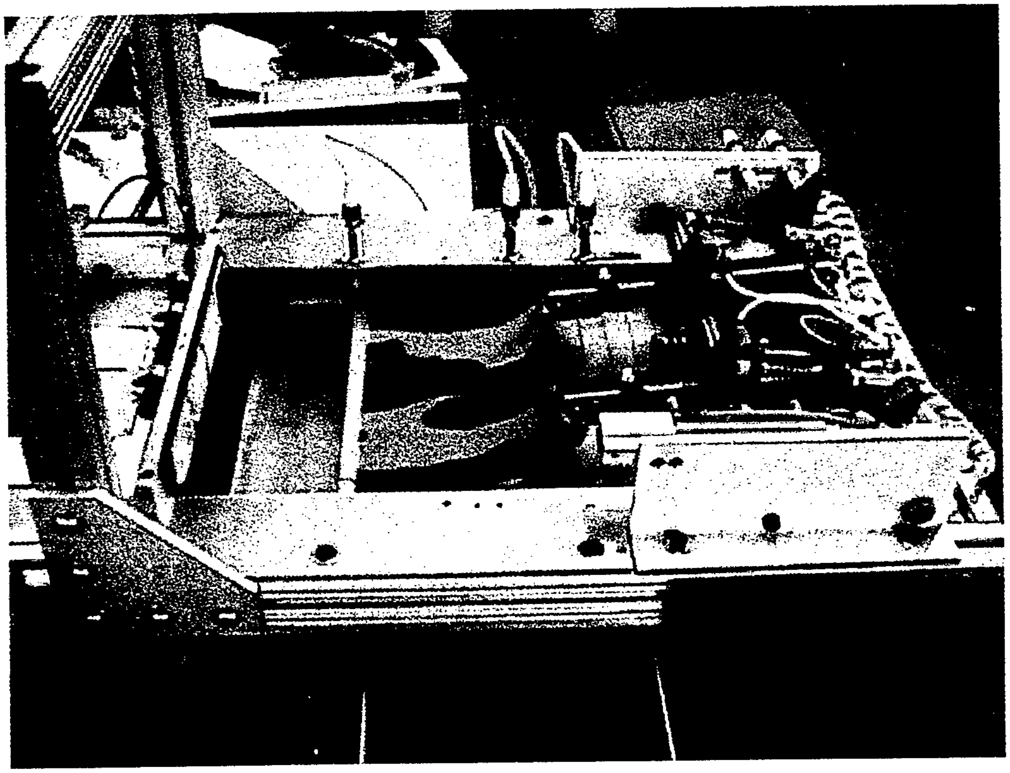


Figure 2.6. Adjustable Feeding of Various Size Pocket Flaps

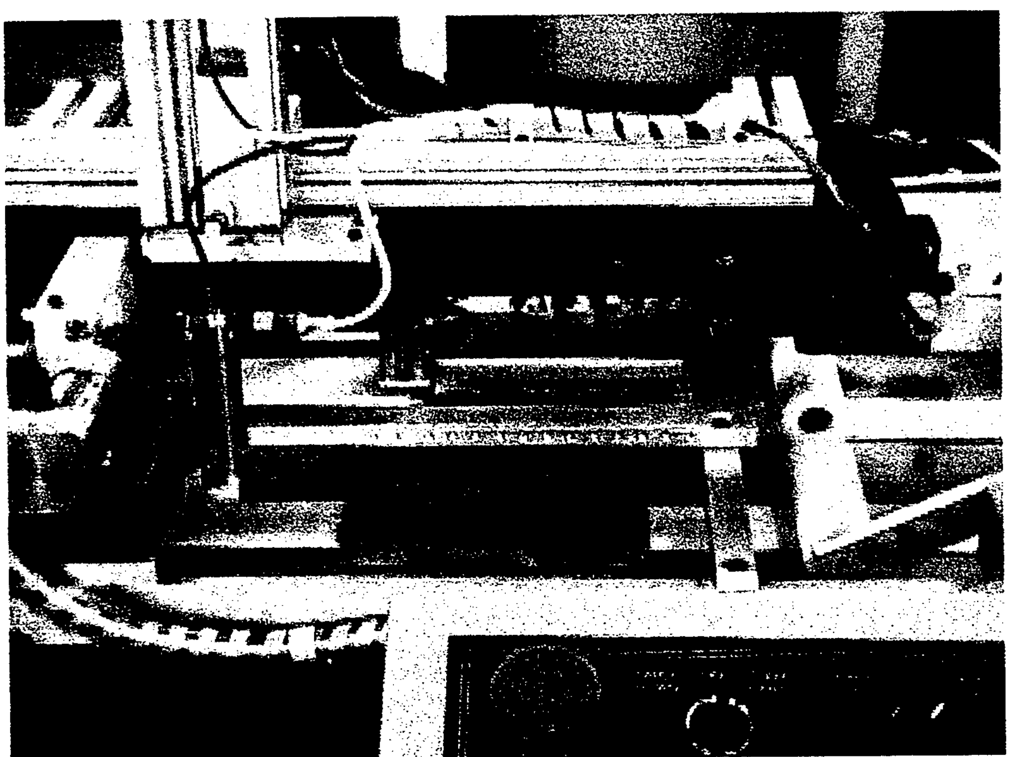


Figure 2.7. Uniform Alignment System

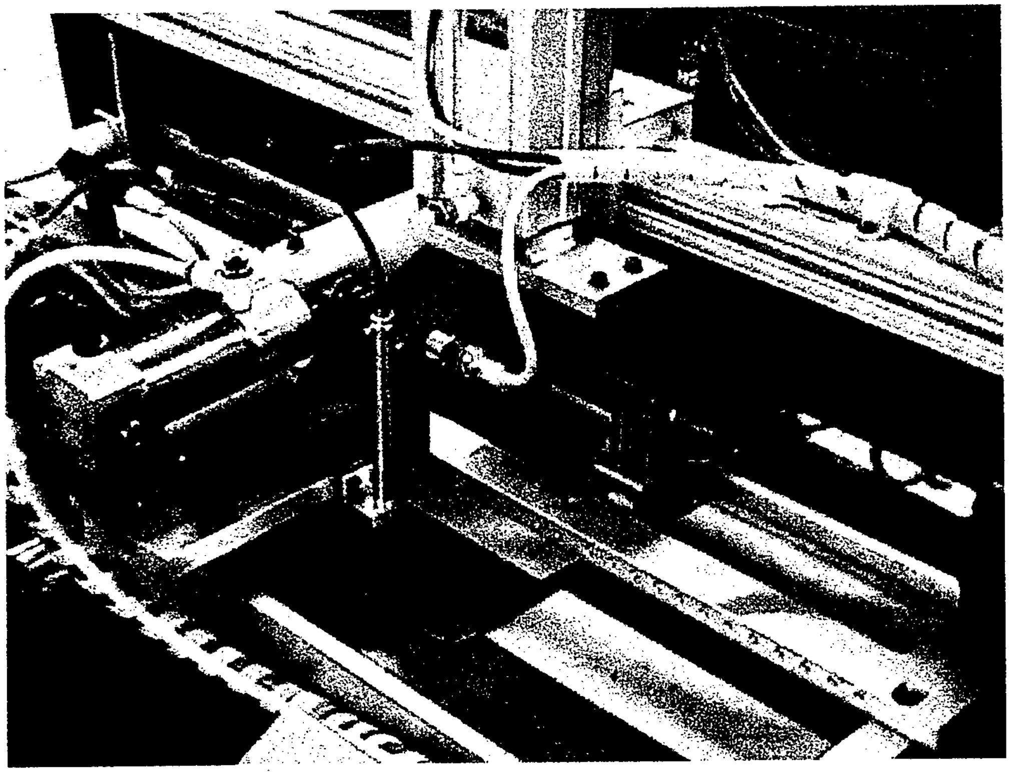


Figure 2.8. Programmable Fusible Length Adjustment

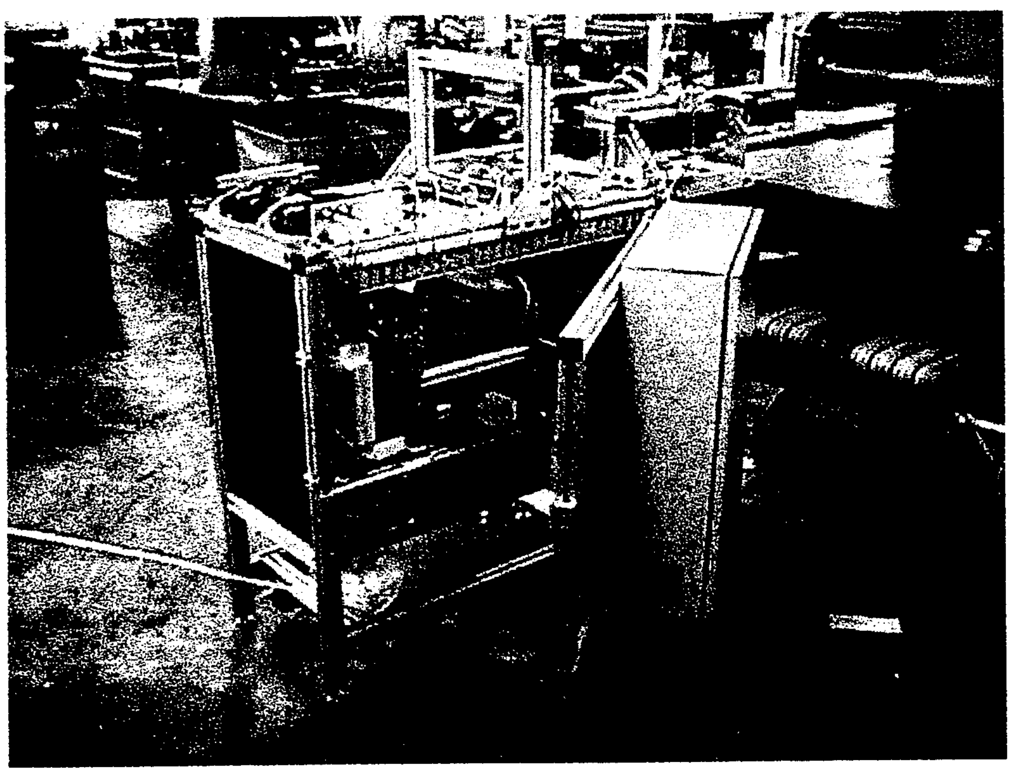


Figure 2.9. Easy Accessibility for Maintenance

Figure 2.10. Simple PLC Electronic Controls

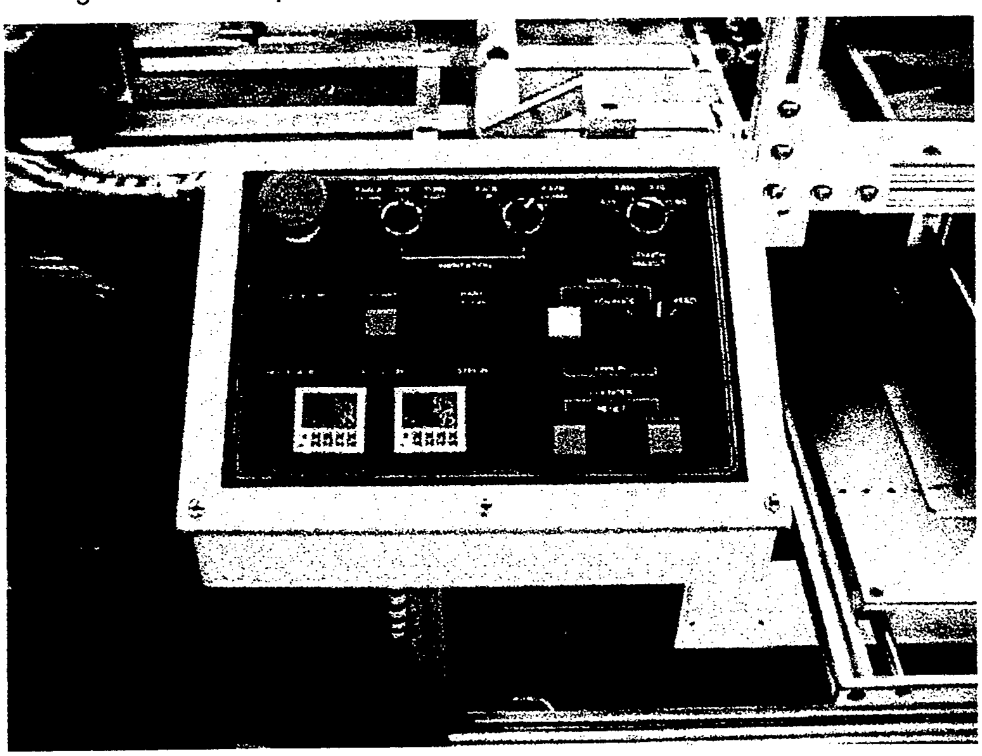


Figure 2.11. Operator-Friendly Control Panel

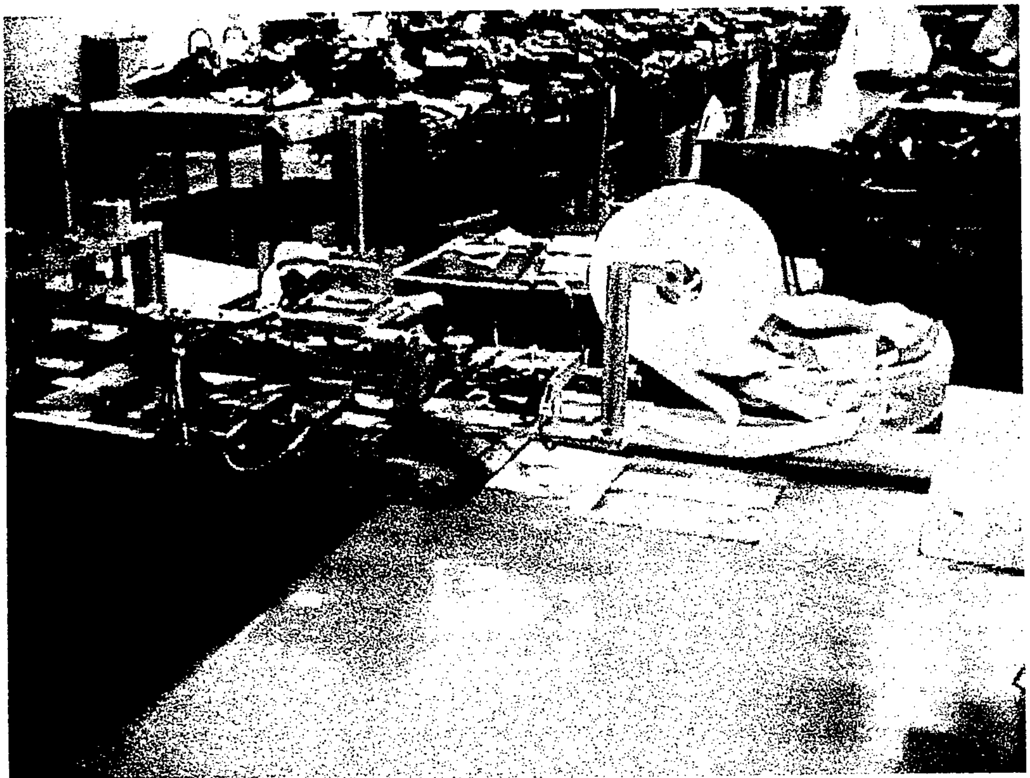


Figure 2.12 Accurate Placement of BDU Pocket Flap on Fusing Press

3.0 Metrics

The performance of the automated equipment is judged most accurately by the metrics of performance. The metrics include productivity, economic benefit, quality, surge capacity, mechanical efficiency, training time, and training costs. Table 3.1 summarizes many of these metrics.

Table 3.1. BDU Pocket Flap Fusing Automation POST Metrics

Metric*	Old Value	Resultant Value
DLA-ARN Investment AA Investment	$419K $120K	$523K 10 year NPV (AA) **$1.5M 10 year NPV (all BDUs)**
Direct Labor cost	$205K/yr	$97K/yr **($108K/yr Savings)**
Training Time	8 weeks	2 weeks **(75% Reduction)**
Quality	85% operator defects	10% operator defects **(88% Reduction)**
Surge capacity	1X/operator	2X/operator **(2X , 9 wks faster)**
Training Costs	Ave $8,640/operator	Ave $2,160/operator **($6480/operator savings)**

* Savings Based 1.25M/year BDU production at AA

Figure 3.1 shows a three fold productivity increase when two fusing systems are employed. Figure 3.2 shows a Statistical Process Control chart of the production efficiency over time using just one unit. Figure 3.3 shows the significant reduction in defects produced using the automatic equipment resulting in an 88% reduction in the number of defects generated. Figure 3.4 shows the production efficiency of a new operator learning to operate the automatic equipment. The results show a two week training time versus an eight week period for a manual operation. This results in a reduction of training costs per operator of over $8,500.

The improvements in production, quality, training, and surge capacity all translate into reduced manufacturing costs that can be used to purchase automated equipment and reduce the unit cost of military apparel products. Table 3.2 shows the detailed economic analysis of the impact of the fusing equipment summarized in Table 3.1. This analysis is a conservative analysis because only the direct labor savings are used in the calcualations. Improved quality, reduced training costs, and other factors that reduce manufacturing costs are not included.

The return on investment (ROI) is highly favorable in light of contract awards that have time periods exceeding two years. Military contractors have, in the past, been reluctant to purchase expensive automation. Now we have the equipment and the metrics to prove that their investment is low risk.

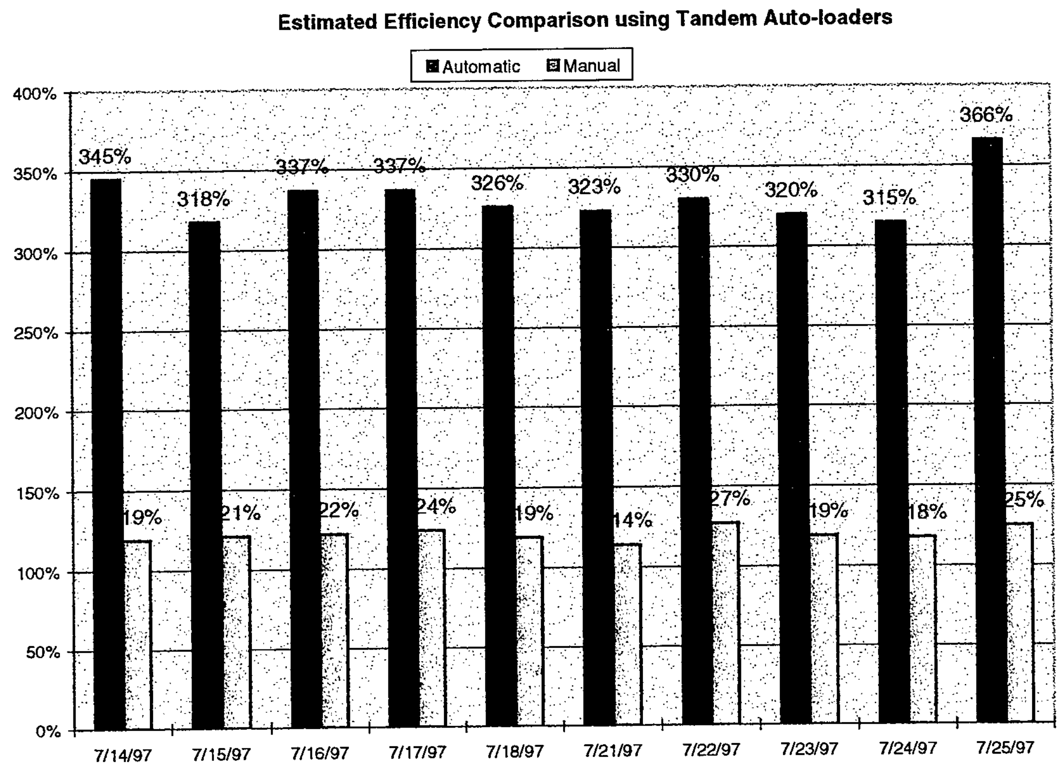


Figure 3.1. Production Efficiency Comparison of Tandum Automatic Units Versus Manual

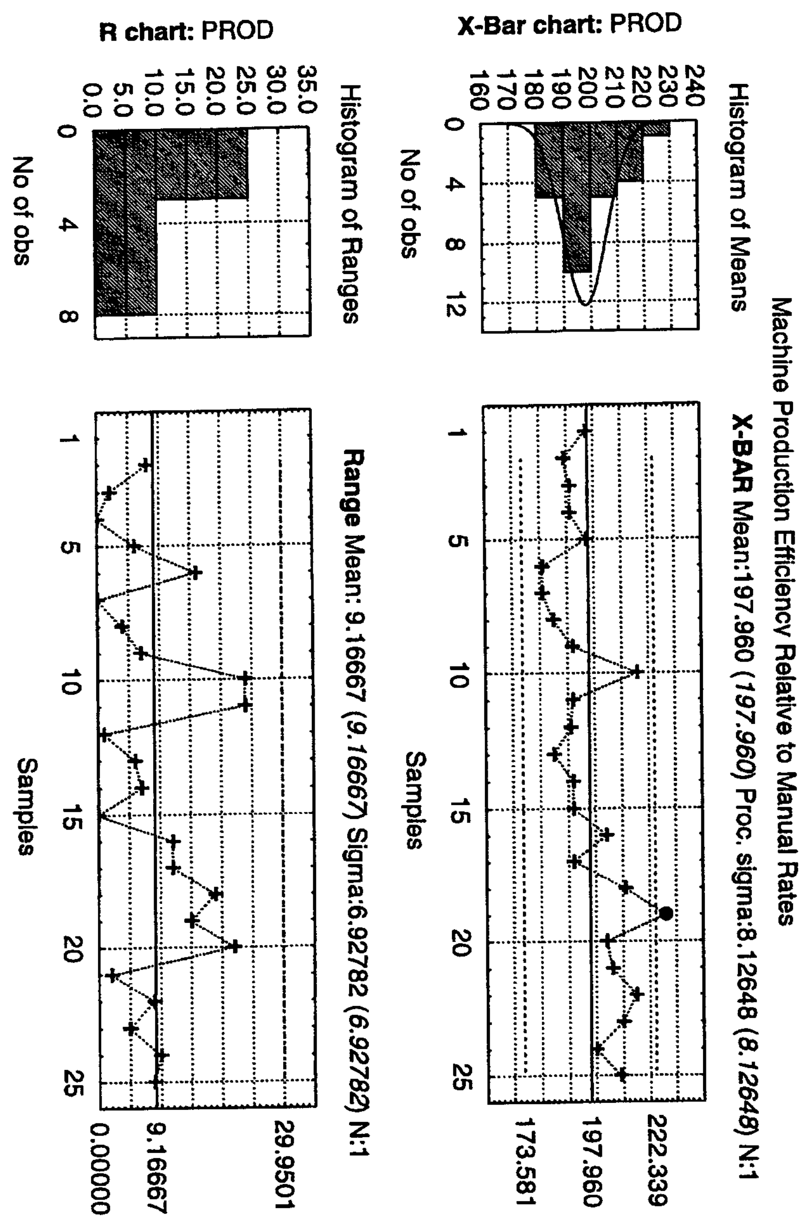


Figure 3.2 Statistical Process Control Charts of Production using One Unit Only.

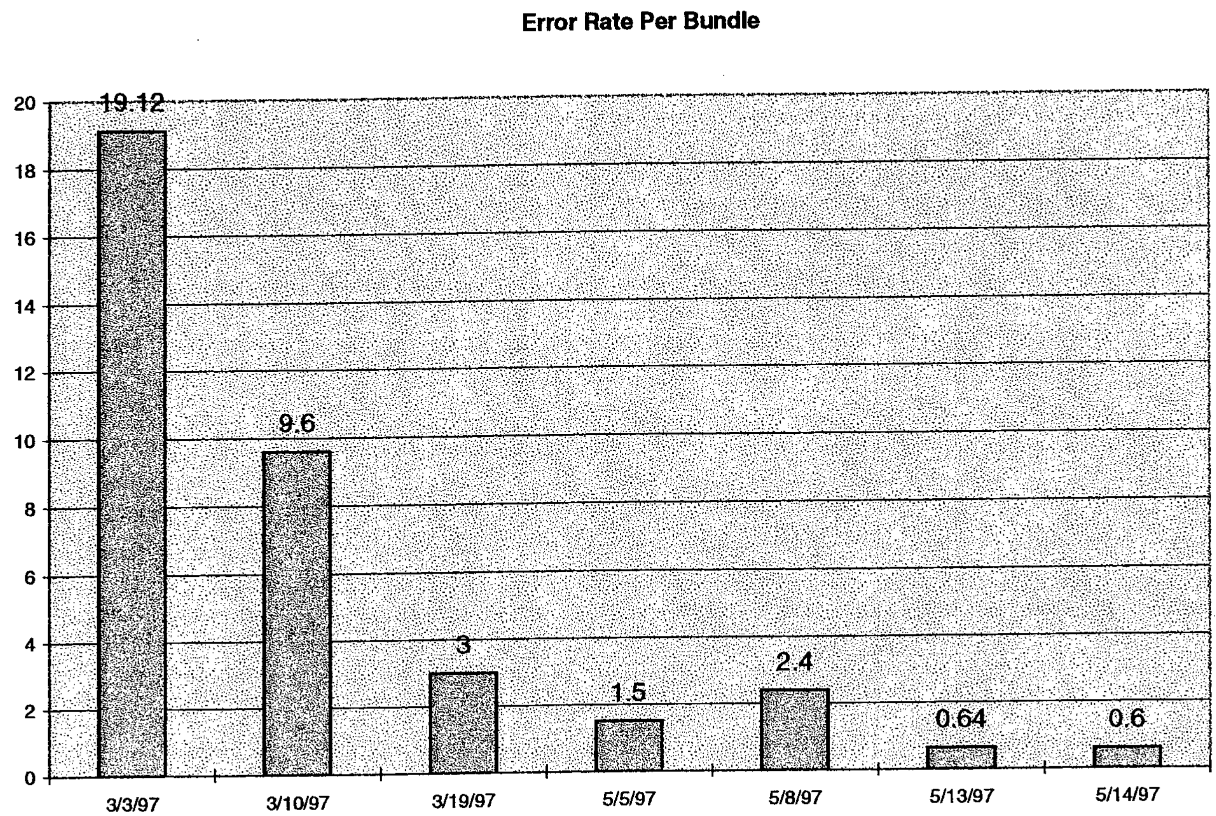


Figure 3.3. Error Rate Reduction Using Automatic Equipment

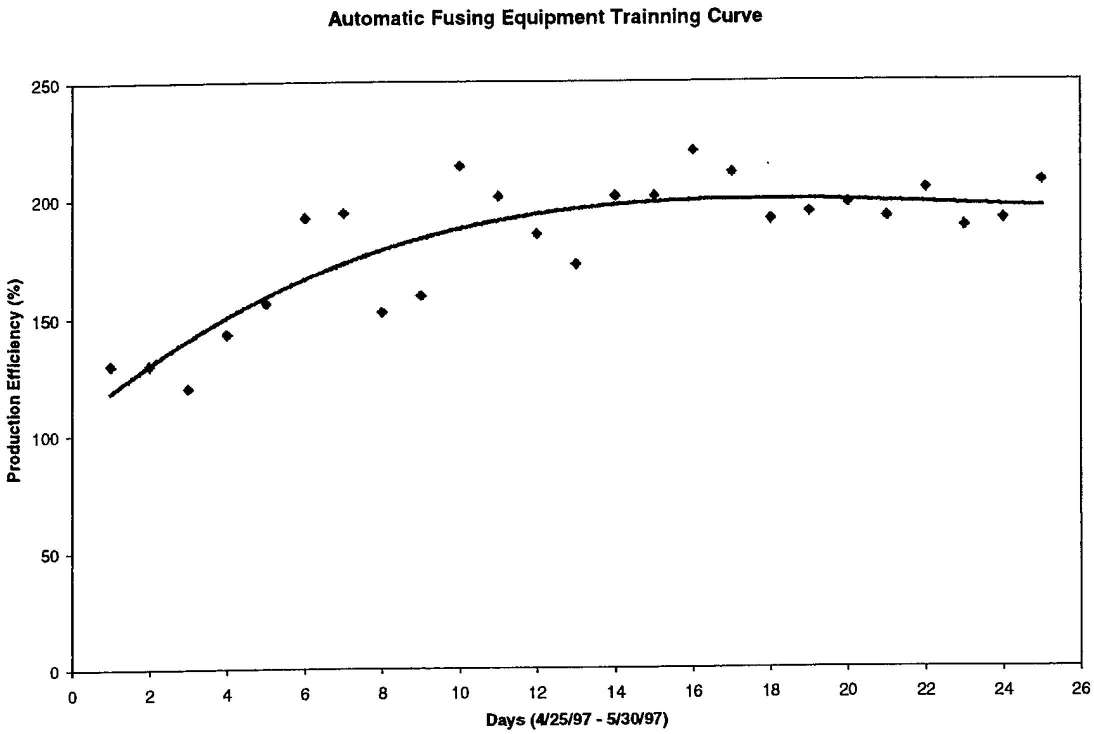


Figure 3.4. New Operator Production Efficiency Versus Time

Table 3.2. Detailed Economic Analysis of Automatic Fusing Equipment

Present Rates	Units 8/Hrs.	S.A.H.	
Fuse Top Flaps	1852	0.004320	
Fuse Btm Flaps	1852	0.004320	
		0.008639	**Total SAH**

Proposal
Automatic Loader
1 operator running tandem machines

Proposed Rates	**Units 8/Hrs.**	**S.A.H.**	
Fuse Top and Bottm Flaps	1852	0.004320	
Total Proposed S.A.H.		**0.004320**	
Savings:		0.004320	**Total Proposed SAH**
Weekly Production:	**28,000** * includes 3000 trousers per week	120.95	Hours/week savings @ $18.00/hour cost
		$2,177.11 Weekly	
		$108,855.29 Yearly	

Cost To Implement:

	Cost per machine	Total Cost	Machines required
Automatic Loader	$25,000.00	$100,000.00	4

ROI		With fusible savings
Weekly Production	28,000	28,000
Weekly Savings	$2,177.11	$2,860.31
Weeks to ROI	46	34

Additional Savings on Fusible

Top Flap Die Cut Fusible	$0.030 Per coat	
Btm Flap Die Cut Fusible	$0.039 Per coat	
Total Fusible Cost/Coat	$0.069	
Slit Fusible	$0.045 Per coat	
Savings	$0.024 Per coat	
Weekly savings	$683.200	28,000 units per week
	$34,160.000 Yearly savings	

$143,015.29 Total yearly savings in labor and materials

4.0 Technology Transfer

A strategy to transfer the technology to other military contractors and other military apparel products has been developed. The strategy targets several areas which include: military contractors, civilian contractors, and machinery manufacturers.

The strategy begins with the "customized" commercial equipment development using the "building blocks" of technology to automate apparel manufacturing. Small to medium size equipment manufacturers utilize this technology to design specialized equipment for specific military apparel assembly operations, such as BDU pocket flap fusing. Utilization of the building blocks greatly reduces the expense and time to design this custom equipment. This strategy helps keep design costs at a minimum.

Mid-South Sewing Machine Sales and ARK, Incorporated have experience designing and manufacturing equipment utilizing this technology. ARK has production equipment running at Tennessee Apparel in Tulahoma, Tennessee and at American Apparel in Fort Deposit, Alabama. Mid-South has several different machines running at American Apparel. Both machinery companies can produce customized commercial equipment for other military contractors at justifiable equipment cost.

Efforts to inform the military and the civilian contractors is conducted through the presentations at government contractors meetings, at DSCP meetings, at trade shows such the Bobbin Show, through electronic media on websites, and through direct mailing to military contractors.

A video describing the equipment operation and the benefits of using automation has been produced. The video has been shown at meetings and given to contractors interested in the technology.

At the heart of the technology transfer strategy is the operation of the equipment in actual production in a military contractor's facility. The metrics are compiled directly from production data collected in actual production. Military contractors interested in the technology can see the equipment running in a production environment and speak directly to the users of the technology. Tennessee Apparel and American Apparel have demonstration equipment. Open tours have been conducted at each facility.

Future plans include inviting groups and individual contractors to visit the demonstration sites. Mid-South Sewing Sales is producing promotional materials describing the benefits of the equipment and its utilization to other apparel assembly operations.

The technolgy transfer strategy has been implemented. Table 4.1 contains contacts for additional information. Commercial equipment is available for sale. Two equipment manufactuers can build equipment to meet specific requirements of military contractors at justifiable costs. This information is being dissiminated through a broad spectrum of communication mediums. As the military contractor community benefits from this technology, DSCP will see benefits in unit costs, quality, surge capacity, and on-time delivery.

Table 4.1 Contacts for Additional Information Regarding Equipment

NAME	ADDRESS	TELEPHONE
Mid-South Sewing	P.O. Box 1974, Tucker, GA 30085	770-939-3195
ARK, Incorporated	P.O. Box 636, Shelbyville, TN 37160	615-684-4737

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- ARK, Incorporated for the engineering design and apparel experience to develop many of the building blocks of apparel automation and for the automated BDU pocket flap fusing production prototype,
- Mid-South Sewing Machine Sales for designing, constructing, and installing the BDU pocket flap fusing commercial equipment, and
- American Apparel for actively participating at every stage of palnning, design, installation, and evaluation of the equipment.